Vol. XXXVI. DECEMBER, 1896.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

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No. 784.

THE CONSTRUCTION OF A LIGHT MOUNTAIN RAILROAD IN THE REPUBLIC OF COLOMBIA.

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PRESENTED AT THE ANNUAL CONVENTION, 1896.

WITH DISCUSSION.

In the construction of a railroad in a country where sufficient traffic is already in existence to warrant a fair return on the contemplated investment and where capital can be easily procured, the main object should be to build the road with such light curves and grades that the operating expenses may be kept down to the lowest limit, almost regardless of first cost, as long as the interest on the additional capital required does not exceed the saving that will be effected in the operating expenses by the additional outlay, as in that manner the line will be in a condition to face active competition. On the other hand, where a railroad has to be built in a new and undeveloped country to accommodate a light traffic which is not expected to increase materially for many years to come, and where capital is limited, it becomes necessary to adopt sharper curves and heavier gradients than customary, if, by so doing, the first cost of construction can be decreased to such an amount as to make possible an enterprise of otherwise

prohibitory cost. The purpose of this paper is to describe a railroad of this nature, built for the Caribbean Manganese Company of Baltimore, Md., in the Department of Panama, Republic of Colombia. The main line of the road at present in operation is 9 miles long and extends from the harbor of Nombre de Dios to the Nispero and Soledad manganese mines. The Nombre de Dios Harbor is on the Caribbean Sea, about 40 miles northeast of Colon.

During the spring of 1892 the author was requested to make preliminary surveys and estimates for a railroad from the mines which had recently been discovered, to the nearest and most appropriate place on the coast available for shipping purposes. An examination of the coast showed that there were only two places to be considered, Viento Frio and Nombre de Dios, the former being 5 miles east of the latter. Both were inhabited by a few native villagers whose only communication with the outside world was by means of their canoes, as there was no vessel running to either locality, except an occasional trading schooner which would stop far from shore and take in a small load of cocoanuts or ivory nuts. No plans or chart of that portion of the coast having ever been made, approximate hydrographic surveys of both harbors were made to determine their future possibilities as shipping ports. The investigation revealed that Nombre de Dios would make a fairly good port, while Viento Frio could not be used at all unless a large amount of coral rock was blasted and dredged.

A general exploration or reconnaissance of the country lying between the mines and the two ports was then made, which was a very difficult undertaking, as the country was covered with a dense forest or thick undergrowth, the larger portion of which had never been penetrated, except, perhaps, by a few natives. There were no roads and very few footpaths. The investigations had to be carried on generally by wading and following up the streams and creeks, by ascending to the top of adjacent hills or climbing trees at convenient localities from which to ascertain the topography of the surrounding country. It was finally decided that the most economical route for the railroad would be the one following the general direction of the Viento Frio River, as it was discovered that between the mines and the sea there are ranges of hills running parallel to the coast which only appeared to flatten out when they approached the narrow valley formed by the Viento Frio River.

Preliminary lines were then run from Nombre de Dios and Viento Frio to Nispero along the general route selected by the reconnaissance. The progress of this survey was very slow, as it depended almost entirely on the progress made by the natives in cutting out the line with their machetes through the thick undergrowth. The average progress varied from 2 000 to 4 000 ft. per day. Topography was taken on both sides of the line, covering a belt of country from 200 to 500 ft. in width. The whole line was afterward plotted on a scale of 400 ft. to the inch. The line from Viento Frio to Nispero turned out to be 6½ miles long, and the one from Nombre de Dios 8½ miles. The former was the shorter and cheaper line, but the saving in its cost was far from compensating for the large expenditure which would have to be made to improve the Viento Frio harbor. For that reason the author, in his report made to the company in July, 1892, advised against the construction of that line, and, after weighing all considerations, recommended the construction of the railroad from Nombre de Dios as the more economical line.

During the latter part of December of the same year he was asked to take charge of the work to be carried out in Colombia, and was informed at the same time that there had been many difficulties in obtaining the right-of-way to Nombre de Dios, so the company was forced to build the railroad to Viento Frio. As no improvements in the harbor were contemplated, the ships would have to anchor outside and receive their cargoes by lighters. During some portions of the year this was possible, as the dead calm prevailing in that latitude made the sea very smooth, but at other times the prevailing trade winds made the sea so rough that it would have been impossible to ship at all. For this reason it was decided to send only a few shipments from Viento Frio, in the hope that the right-of-way matter would be settled in the meanwhile, and then proceed to Nombre de Dios.

During the latter portion of 1892 Mr. E. G. Williams had been sent by the company to make surveys from Viento Frio to Nispero along more direct routes; but his estimates proved that any such routes would cost twice as much as the one proposed by the author.

The location of the railroad was therefore made along the Viento Frio River route, and it was started during the first week of February, 1893. The average rate was in the neighborhood of a quarter of a mile per day. Although the plans of the original preliminary

were carried in the field for constant consultation, no attempt was made to follow the paper location. Maximum curves of 40°, 146 ft. radius, and maximum grades of 5% in favor of traffic, were adopted, so as to reduce to a minimum the amount of excavation to be made. The only adverse grades were some short ones of 1 and 1½ per cent. As it was only in the last mile that the natural level of the country rose very rapidly, it was possible to concentrate all the heavy grades in that portion of the line, which made operating very convenient, as by placing a switch at the foot of the grade the locomotive can haul to it a large number of empty cars and from there to the mines make as many trips as the number of sections into which it is found necessary to divide the train.

The country being broken by a large number of gulches and creeks, a corresponding number of small bridges was required to cross them. All the drainage of the portion of the country under consideration is carried to the sea through the Viento Frio River. This has a very moderate velocity in ordinary stages and is only from 40 to 80 ft. in width, but during the rainy season and in time of flood, like most of the tropical streams, carries a large volume of water with a corresponding increase in velocity. The located line crossed this river twice, and its tributary, the Mamey, four times. In all these cases it was found cheaper to bridge across than to keep on the same side, as either the increase in the length of the line resulting from following the windings of the stream or the increase in excavation due to the much rougher mountain side would have added considerably to the expense of construction. In locating the line along the side hills it was fitted as close as possible to the natural formation of the ground, and it was placed in cuttings so that the whole road-bed would rest on solid ground, as no embankment could have stood on the steep side hills, washed at the bottom by a stream that would carry away any embankment, not formed of broken rock, which would come within the limits of its high-water mark.

After the location was completed the older estimate was revised and a new and careful estimate was made of the cost of constructing the railroad from Viento Frio to Nispero, including the equipment necessary to begin operations at the mines, as well as the lighters required at the port for shipping the ore. This estimate had to be approved by the Board of Directors of the company in Baltimore before any

work of construction could be started, but while waiting for further orders, the clearing and grubbing of the line was executed and work suspended in May. Construction was finally started in January, 1894. It was found that the right-of-way which had been cleared and grubbed seven months previous was covered with luxuriant vegetation, attaining in places heights of 5 to 7 ft. Some of the center stakes furnished proof of the extreme vitality of the vegetation in that portion of the tropics, as they seemed to have been imbued with new life and were covered with green leaves.

After the clearing had been performed several places were found in going over the line, as is usually the case, where improvements could be made in the alignment, and changes were made accordingly, although not as many as desirable, because the work of grading was pushed so rapidly as to give the engineering corps no time for making minor changes. The last mile, however, comprising the most difficult portion of the work, was gone over. The previous work was platted to a scale of 100 ft. to the inch. A new location was made on paper, and trial lines following the paper location closely though not exactly were afterward run on the ground until the result was as satisfactory as the nature of the country would allow.

It was believed that the cargo of material, comprising rails and fittings for 6¼ miles of track, timber, cars, a locomotive and other items, would arrive about May 1st at Viento Frio, but various causes delayed the accumulation of sufficient rails and timber to begin work until about August 1st, when track-laying and bridge-building were started.

The bridgework was a source of considerable trouble, as the chief carpenter expected from the United States never arrived. None of the so-called carpenters engaged in the neighborhood could understand or work from plans, and their workmanship was so poor that, even after laying out the whole work for them, they had to be watched closely to keep them from spoiling the timber. It was not until after half of the work had been accomplished in this manner that a few fairly good carpenters were secured; the work then proceeded at a better rate and with little interruption.

Owing to these difficulties, it soon became evident that the first shipment of ore could not be sent from Viento Frio about the middle of September, as had been expected, and if the shipping was delayed

much longer, the season would be so far advanced that the risks of loading vessels at this port would be considerably increased. In the meanwhile the relations between the company and the owners of the land around Nombre de Dios had become more cordial, and finally satisfactory arrangements were concluded for the right-of-way. This did away with the necessity of shipping from Viento Frio, and it was decided to extend the line to Nombre de Dios. The distance from this port to the nearest point on the line of the completed railroad was 4 miles. The location was started from that point, which was 1½ miles from Viento Frio. For the first mile the line skirts the flanks of the mountain to escape crossing a swamp which extends from its foot to the coast. From the beginning of the second mile to Nombre de Dios the line is built wholly on embankments, as the mountains recede from the coast, leaving a wide plain between them and the sea, which is covered by lagoons and swamps narrowing considerably as they approach the coast. For this reason the line was located closer to the coast than to the mountains, and it was possible to employ easy curves and long tangents. The ground close to the line was considerably improved afterward by drainage ditches. The location and some of the clearing were performed during the worst part of the rainy season, and a large portion of the plain was covered ankle deep with water. It was considered unadvisable for hygienic reasons to commence grading before the rainy season was nearly over, or about January 1st, 1895.

The material for the extension arrived in Nombre de Dios by schooner on March 1st.

The first train of manganese ore from the mines to Nombre de Dios was run about April 20th, and three weeks later the steamship *Earnwell*, the first steamer ever seen in Nombre de Dios Harbor, came in and took away the first cargo of ore. Later on, the railroad was extended half a mile more from Nispero to Soledad.

Clearing.—The clearing and grubbing of the road from Viento Frio to Nispero cost $360 per mile. The forest and undergrowth were very heavy. The view shown in Plate II, Fig. 1, was taken while the clearing was going on. As the general direction of this line was north and south, the clearing was made wide enough to allow the sun's rays to penetrate during a large part of the day, and in that manner contribute to the quick drying of the roadbed. The average width was about

FIG. 1.

FIG. 2.

100 ft., 50 ft. on each side of the center line; but on steep side hills the clearing was carried on the upper slope to 75 ft., and at times 100 ft. or more from the center line, so as to prevent trees from falling down to the track after the road was in operation. In spite of this care nearly a year after a certain portion of the line had been completed, and shortly after the author returned to the United States, he was informed that a tree which had been left standing about 200 ft. from the track and was thought to be a safe distance away, was undermined by very heavy rains, came down the side hill at a rapid rate and damaged the track and the end of a trestle. This instance is given to show that in countries where excessive rains cause rapid erosion, not much reliance can be placed on the apparent stability of trees on side hills, and the clearing on the upper portion of the slope cannot be made too wide to secure absolute immunity from trouble caused by falling trees.

The clearing and grubbing of the Nombre de Dios branch cost $197 per mile. The cost was less than that of the former line, because, the general direction of the line being east and west, the clearing was not made so wide. The average was about 60 ft. Moreover, portions of the ground had been under cultivation and the clearing was not so heavy as along the former line.

The whole line was divided into small sections which were given by contract to one or more laborers. The prices varied according to the nature of the vegetation to be removed and were below what similar portions had cost in the former clearing, which had been done by the day. This work was mostly done by natives, as they are superior to the Jamaica negroes for labor of this nature, where axes and machetes are the only tools required.

It was difficult to get the natives to take the contract for clearing a portion of the line where manzanilla, a very poisonous tree, was abundant, but those who finally did the work proved that their fears were not entirely unfounded as some of them were afterward confined for several days with a mild attack of blood poisoning, their faces becoming so swollen that it was difficult to see their eyes.*

* This seems to be produced by the sap coming in contact with any portions of the skin. Its principle antidote is sea water, which is fortunate, in that the tree only flourishes along the coast line, at least in the portion of the country referred to in this paper. The method generally pursued by the natives for getting rid of these trees is to build a fire around them, and after they are partially burned allow them to dry out, although in the construction of the railroad time could not be spared for the completion of the latter operation. The tree bears a fruit resembling a very small apple, which is also poisonous.

Earthwork.—The total amount of material handled in the 10½ miles of road graded was 94 670 cu. yds., most of which was tough clay. The approximate classification of the material encountered was about as follows: 67% of tough clay; 20% of earth or heavy soil; 11% of shale and decomposed rock, and 1% of hard rock, which was chiefly confined to the last mile. The cost, regardless of classification, was 20 cents per cubic yard, including the cost of tools and explosives and the drainage ditches along the whole line of the railroad. About 64 670 cu. yds. was taken from cuts, and 30 000 cu. yds. was used in embankments. Nearly all the latter being light, but few attempts were made to balance the cuts and fills, as it was thought cheaper in this case to waste in cuts and borrow from the sides for the fills. The deepest center cut was 35 ft., but as most of the cutting was on steep side hills, much lighter cuts made the upper slope stakes reach heights of from 50 to 70 ft. above the grade line. All the light work was given out by contract in small sections, varying from 100 to 1 000 ft. in length, to one or more laborers. To avoid disputes the prices were not given per cubic yard, as few of the men had any idea of what that measure represented. The contents in each section was calculated by the engineers and the prices were given for each separate section without stating its contents. Center stakes were placed every 50 ft., and on the sharp curves every 25 ft. Slope stakes were placed to correspond with each center stake. The prices varied from 12 cents per cubic yard for low fills made by shoveling from the sides to 16 cents per cubic yard for tough clay in the cuts and higher embankments. All the heavy work was done by the day, except such portions as could be conveniently given by the piece. Whenever it was possible to give out any work by the piece, that system was preferred, as it invariably proved cheaper and quicker than day work. For some time after the first small contracts were given out, whether for clearing, grading, felling and hauling timber, hewing or any other work, a record was kept of the number of men and the time employed in carrying them out, so as to determine the wages they were making and find if the unit price was susceptible of still further reduction. In this manner a large portion of the work was carried out more cheaply than would have been possible by day labor.

In pick and shovel work, and, in fact, in nearly all manual labor except clearing and seamanship, the Jamaica negroes proved superior

to the natives. Their pay in ordinary work was about $1 or $1 20 per day of the silver currency of the country, which at that time was equivalent to nearly 50 and 60 cents American currency respectively. Their efficiency as compared with American labor is in nearly the same proportion as their respective rates of pay. Under good discipline they are easily managed, and on account of their partial immunity from the unhealthy effects of the climate they are valuable aids to any enterprises in this portion of the tropics.

The embankments were made only wide enough to allow the track to be laid on them, or from 7 to 8 ft. It was expected to make them wider after the completion of the road, and while shipments of ore were going on, because the traffic being very light it would allow the train crew plenty of time to haul the refuse from the mines and dump it over the embankments. In this manner, while the cost of construction was decreased slightly, the cost of operation would not be very much affected. In ordinary cases, however, the author would not recommend the building of embankments less than 10 ft. wide for a 3-ft. gauge road, particularly where the rainfall is heavy, as what is saved in dirt will be lost in ballast where sufficient room is not left between the ties and the edge of the embankments. The cuts were made 10 ft. wide. This is the least dimension which it is advisable to adopt, so as to allow room for the water to run off, and 12 ft. would be much better. Several slides occurred in some of the cuts after completion, but they were not as many as had been anticipated from the heavy rainfall.

Bridges.—There were 2 489 lin. ft. of bridges built; 2 093 ft. were pile trestles, and 396 ft. were framed trestles resting on mud sills, and varying in height to 30 ft. In length they varied from 15 to 120 ft., except the pile trestle built to the ore dump at the port, which measured 285 ft. The total amount of lumber consumed was 121 800 ft. B. M., exclusive of piles, which numbered 374, and added 6 600 lin. ft. Of the lumber 43 500 ft. was Georgia pine shipped from Baltimore, and 78 300 ft. was native timber. The former cost from $40 to $45 per thousand feet, after paying freight, unloading and transportation to site. The cost of felling, hewing and hauling to site the native timber varied from $15 to $35 per thousand feet, depending on the distance and nature of country through which it had to be hauled.

The piles were all of native timber, and were delivered in place for 9 cents per lineal foot, which made the cost of the average pile about $2 20. The average penetration varied from 8 to 12 ft. Nearly all the piles were driven before the arrival of the track material by means of a light pile-driver with a 1 000-lb. hammer and a hand winch. The pile-driver was transported on a cart from site to site on the completed road-bed, and the cost of driving the piles of the first six miles, from Viento Frio to Nispero was $5 95 per pile, including the cost of the pile-driver and cart. During the construction of the 4-mile branch to Nombre de Dios, a modification was made in the system of transporting the driver which proved very satisfactory. Instead of a cart, a portable track and cars, which had been bought for use at the mines, were utilized. This track of 20-in. gauge came in sections about 15 ft. long, which were easily carried by two men. About 300 ft. were laid on the roadbed, and four of the small mining cars transformed into platform cars were placed on this track. On the first two the driver was loaded and pushed to the end of the track. The other two cars were kept in the rear to carry the rails, which were taken up as the pile-driver advanced. As soon as they came close to the latter, the rails were taken from the rear cars and laid ahead. The process was repeated until the driver reached the desired point. In this manner progress was more rapid and not interrupted by the mud formed by heavy rains. The cost of driving the piles in this case was $4 80 per pile. The decrease in the cost was not only due to the change in the system of transporting the driver, but also to the increased efficiency of the labor by their former experience, and better average weather. It is not believed that the result would have been more economical had steam been used as motive power, considering the increased difficulty in moving the driver along the newly made embankments, and the higher wages which it would have been necessary to pay for skilled labor. Had the piles been more numerous, and a larger number of them in each bridge, the increase in speed resulting from the use of an engine would have warranted the expense, but as the pile-driver followed the grading gang, and most of the piles were driven before the other bridge material arrived, nothing would have been gained by the use of a steam engine.

The average cost of the completed trestles, including all material

and labor, was $4 20 per running foot. They were designed for the use of 15-ton locomotives.

The pile bents were composed of two or three piles according to their height, braced laterally by 2 x 12-in. planks. Posts, sills and mud sills of framed trestles were 10 x 10 ins.; caps 10 x 12 ins. and 8 or 9 ft. long. Stringers when of native timber, for 15-ft. spans were made of 12 x 14-in. single sticks under each rail; for 20-ft. spans they were 15 x 18 ins., although both sections were increased whenever the size of the timber from which they were hewn made it possible to do so. The bolts and drift bolts used were $\frac{3}{4}$ and $\frac{5}{8}$ in. in diameter. The framed trestles were braced laterally by 2 x 12-in. pine, and longitudinally by 5 x 8-in. pine sticks. The two inner posts were made plumb, and the two outer posts were given a batter of 3 ins. to the foot, except in the trestle on the 40° curve, where the post on the outer side of the curve was given a batter of 4 ins. to the foot. In the case of some of the bents on a steep rocky bottom, instead of leveling this off, as would have been required had a sill been used, it was found cheaper to locate the places where the posts would strike the rock, and, after drilling and blasting four holes about 18 ins. deep, and from 18 to 24 ins. in diameter, the posts were placed in them and the vacant spaces filled with cement. About 500 ft. of bridges are on curves. One pile trestle 110 ft. long and 13 ft. high, and one framed trestle 80 ft. long and 22 ft. high, are on a 40° curve. In both cases the stringers used are of pine, bent to form the curve. Before starting this operation the bents must be thoroughly braced, as otherwise the elasticity of the timber will tend to displace them. In this pile trestle the spans are 15 ft., and the stringers are made up of three 6 x 12-in. sticks 30 ft. long under each rail and breaking joints. In the framed structure the spans are only 12 ft., and the stringers are composed of two 6 x 12-in. pieces 24 ft. long, placed under each rail and breaking joints.

The superelevation of the outer rail in curves was calculated for low speeds; the maximum adopted was 4 ins. for the 40° curve. The difference in elevation was generally made up in the posts, except when the superelevation was under $1\frac{1}{2}$ ins., when the lower rail was dropped that amount by hewing down the tie. The rails used for inner guard rails were of the same section as those in the main track.

The pile trestles built across the Viento Frio and its tributary, the

Mamey, have stood without accidents the successive floods of two rainy seasons. The spans in these cases were made 20 ft. wide, and as no longitudinal braces were employed and the three piles in each bent were driven parallel to the current, they offer the least surface of resistance to the flow of water in time of flood. The great danger lies in the amount of drift wood generally carried down, as shown in Plate II, Fig. 2. This view was taken after a flood, when the drift which had accumulated against bridge No. 31 was being removed. This is the pile trestle on the 40° curve already described, the outside of the curve being toward the up-stream side. This makes the trestle act like an arch to resist the thrust of the drift, which is particularly likely to be stopped here because the spans were reduced to 15 ft. on account of the sharpness of the curve. The bridge was not damaged, but about 20 ft. of the embankment shown in the view was washed away. This happened during the first rainy season after the construction of the road had been started, when there were many logs and pieces of wood from the clearing which were not dry enough to burn and found their way to the streams during the first floods. The first and second rainy seasons having taken away most of this wood, it is not likely that any of the bridges will be submitted to the same strain in the future, and with a little watching to prevent accumulation of the drift wood there seems to be no reason for entertaining any fear on that source.

Colombian Timber.—Very little is known as to the durability of the native timber in the Department of Panama, as on account of the lack of transportation facilities it has generally been found cheaper to use pine imported from the Southern States. It is known, however, that nispero, a very hard wood used extensively for house building many years ago, is still found in good condition in houses said to be nearly a century old. In all these cases the wood was in the interior and well painted and protected from sun and rain, but it is likely that the same wood exposed to the trying weather will last only a small fraction of that time, as the climatic conditions prevailing in the locality, that is, constant heat and excessive humidity, are the most unfavorable for the preservation of any class of timber. Creosoted pine timber has been used very extensively for engineering works in the Isthmus and will outlast considerably the untreated pine.

It is a prevalent opinion in tropical countries that the moon exerts much influence on the vegetation in those latitudes, and the best time

for felling timber is held to be during the six days preceding or following the last quarter of the moon. It is said that timber cut during the period extending from the new to the full moon is shown by repeated experience to become decayed or worm-eaten more quickly than any other, and some facts that came under the author's observation seem to verify the theory.*

Culverts.—Owing to the heavy rainfall, a large number of culverts had to be built. They were sometimes box culverts, made out of pine planks 3 ins. thick, but in many cases they were built of native logs, and made large enough to allow a box to be slipped in after the road was in operation, whenever inspection revealed the necessity of no longer relying on the native timber.

Track.—The rails weighed 35 lbs. per yard. The gauge of track was made 3 ft. Although the author fully appreciates the defects of the narrow gauge, he thinks there are many cases where it can be used to advantage. This is especially the case where no connection with a standard gauge road is expected, and where the first cost of construction has to be watched so closely that even small savings due to narrower road-beds, narrower bridges and shorter ties become of importance, while if the future traffic is expected to be light, the difference between the cost of operating a standard and a narrow-gauge road will be insignificant.

* The roofs of some of the construction camps and dwellings were made of palm leaves. Whenever they were cut during the first quarter of the moon, worms would soon attack them and in about four months they would become useless, while the same quality of palm cut during the last quarter of the moon would seem to resist the worms for a long while and would last about a year, or three times as long as the other. Again, while making the railroad surveys three camps were built along the line and the timber for posts and roofing was cut as required without regard to the condition of the moon. At the end of a year it had been badly eaten by worms. Later on it was necessary to build other camps in the neighborhood, and the same qualities of timber were used from the same locality, but cut during the last quarter of the moon. At the end of a year they had not been attacked by worms, nor showed any signs of decay. The natives seem to have such an implicit faith in this that they will always watch the faces of the moon before felling any timber for their own uses. Nearly all the tropical engineers of experience with whom the author has discussed the subject seem to substantiate the opinion held by the country people, and they make use of that clause in their specifications for native timber. It is possible that the time of greatest activity in the vegetation in the tropics takes place during the first quarter of the moon, and that the sap, being abundant and in rapid circulation, makes the timber unfit for felling; while during the last quarter of the moon the vegetation is probably at rest, making that time the most appropriate for felling. The author makes use of the expression in the tropics, because he does not know whether the fact, or what appears to be an unquestionable fact, has been observed in higher latitudes. If it has not, might it not be due to the greater difference in temperature between summer and winter, which has a tendency to make the periods of greatest activity and rest dependent on the seasons instead of on the much milder effects that the moon could exert? It would be interesting to know what observations have been made by other members of the profession on this matter.

About 2 200 ties to the mile were used, costing on an average 25 cents per tie; their dimensions were 6 x 6 ins. and 5 x 6 ins., by 6 ft. long, although some 5 x 5 ins. were also used. They were hewed out of the native timber in the neighborhood. Some of the ties were rotten within a year from the time they were laid and many more showed signs of decay, but the ties of nispero, sigua olorosa and carbonero seemed to have stood very well. For that reason these three woods, especially the first two, are being used exclusively for repairs, until a longer test can determine the length of their useful life. Some of the hard-wood ties have to be bored before they are spiked. The Panama Railroad, the only other railroad in the Department, uses at present only one class of ties. They are of lignum vitæ, from the valley of the Magdalena River, and are delivered to the Panama Railroad for $1 30, $1 50 and $1 80 per tie, according to their dimensions. The author was shown a portion of a lignum vitæ tie by the engineer of the Panama Railroad, who stated he had taken it from the road after it had been in use for 30 years. Although considerably worn out, it was in a fairly sound condition.

The track laying from Viento Frio to Nispero cost $250 per mile. The work was performed by an American foreman, and all the labor under him from spikers down were new to the work. The large number of small bridges, which prevented an early use of the track in the transportation of lumber, and the inefficiency of the carpenters first engaged, were causes of frequent interruptions to the track-laying gang. In laying the 4-mile branch to Nombre de Dios, where there were fewer bridges to cause interruption, and where the bridge gang, as well as the track-laying gang, had profited by the experience of the previous work, the cost was $200 per mile. It had been the intention to ballast the track only slightly, using as much as possible the material near the track for tamping purposes, and to leave the remaining work for future improvements. It soon became apparent, however, that on account of the excessive rains a larger amount of ballast would be required, and the quicker it was in place, the more satisfactory the result would be. Two cuts along the line of the road, the only ones available for the purpose, were turned into ballast pits, and the material was hauled from them and dumped all along the line. The material was a decomposed rock, requiring very little blasting to handle it, and made a very fair ballast. It was while this work was

going on that it was decided to extend the railroad to Nombre de Dios, but for reasons already stated it was not practicable to begin active work on that line until about January, 1895. It being inadvisable on account of the peculiar location of the work to discharge all the men, as it would have been difficult to find them when again wanted, as many men were employed on the track as was consistent with economy, and in that manner it was brought to a better standard than had been anticipated. This work cost $540 per mile. After completion the road required very little care for some time, and it was in better condition than many passenger roads in Spanish America. The ballasting of the Nombre de Dios branch cost $420 per mile.

Alignment.—As regards the alignment of the line at present in operation, of its total length of 47 048 ft., 17 935 ft. are curves. There being eighty-three of these, the average length is 216 ft. The total amount of curvature to the right is 1 794° 25′, or nearly 5 complete circles. The total amount to the left is 1 914° 57′, or about 5.3 complete circles. Therefore, the total amount of curvature, irrespective of direction, is 3 709° 22′, or about 10.3 complete circles. The longest curve is 847 ft.; it is a 5° curve, with a total angle of 42° 21′. The largest angle is 127° 36′, in a 40° curve, 319 ft. long. There are twenty 40° curves, eighteen 30°, nine between 30° and 20°, twelve 20°, twelve between 20° and 10°, eleven of 10°, and the remainder vary from 9 to 3 degrees. The average degree of curve over the whole of the curve portion of the line is 20 degrees. The longest tangent is 3 906 ft. In the first three miles of the road, starting from Nombre de Dios, there are, besides the tangent mentioned, one of 2 100 ft. and three of about 1 300 ft. In this portion of the line the curvature is very light, and only amounts to 265°, being mostly 5° and 6° curves, with the exception of two of 10°; but after passing the third mile, when the line gets among the hills, the number and the degrees of the curves begin to increase very rapidly. The alignment of the last portion of the railroad is shown in Fig. 1. To avoid confusion the degree of each curve only is shown, and the stations marked every 1 000 ft. The stations are numbered from Viento Frio, not from Nombre de Dios. The profile of the same portion, representing the heaviest work performed, is also shown in Fig. 1. The 5% grade to the Nispero terminal is compensated for curvature at the rate 0.03 ft. per degree of curve;

but owing to the small scale of the profile, only the line indicating the average grade of 4.55% is shown. For the last half mile the 5% grade is laid without compensation, which makes its resistance in the short 40° curve equivalent to that of a 6% grade. The trestles are marked *B*, and the culverts *C*, in the profile, Fig. 1.

Plate III, Fig. 1, shows one of the side hill cuts in the Soledad extension. One of the mining cars used in grading is shown at work. The portion of the line shown on the left of the view is on a 40° curve. This cut furnishes a good illustration of the necessity of the sharp curves in following the sudden turns of the mountains. The Mamey flows at the foot of this hill, but is not shown in the view.

Climate.—Although Nombre de Dios is 9° 36′ north of the equator, the hottest isothermal line passes along that coast line. The average temperature ranges from 78 to 95 degrees. It seldom goes below the former or above the latter, and 86° can be taken as an average temperature. The humidity is always excessive, and according to observations made by the author with a hygrometer, it ranges from 75 to 94 per cent. The more common average varies from 85 to 90 per cent. The author kept a rain gauge at the coast, and the amount of rainfall was recorded every day at 6 A. M. and 6 P. M. The total for the year 1894 amounted to 127 ins. The heaviest rainfall was recorded in the month of December when 26 ins. fell. The maximum rainfall recorded in twelve hours was 6 ins. At the upper end of the railroad much more rain falls than at the coast, probably on account of the thicker and more abundant forest at that end, but no record was kept there. Judging, however, by comparison, the amount of rainfall must have been about 150 ins. during the same year.

There are only two seasons, the rainy and the dry. The former is the longest and extends from the last of April to about the first of January. During this long rainy season, however, there are irregular dry spells of several weeks at a time. On the Pacific slope the rainy season is generally shorter by one or two months.

As soon as the work of construction was started in January, 1894, precautions were taken against the fevers, which it was feared would develop as soon as deep excavations were made in the clay or the swamp work undertaken, particular care being taken about the drinking water, which was at times boiled and filtered. It was not until about May 1st or after nearly all the grading had been accomplished and the

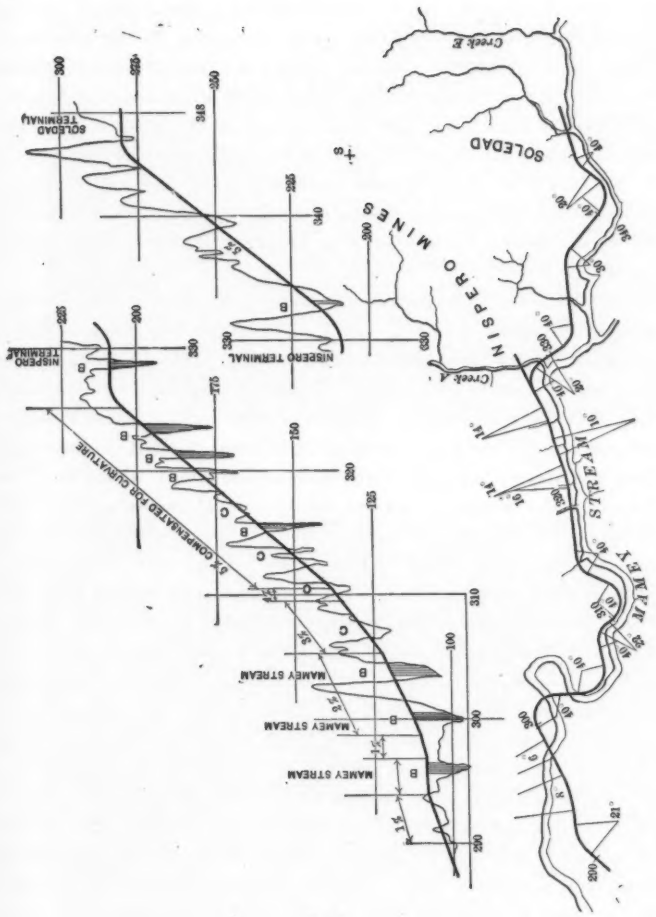
SOLEDAD
NISPERO MINE
NISPERO TERMINAL
SOLEDAD TERMINAL
MANEY STREAM
MANEY STREAM
MANEY STREAM
5% COMPENSATED FOR CURVATURE
Creek E
Creek A

FIG. 1.

rainy season had settled in, that fevers began to spread, and a month later there was not an employee, native or foreign, who had escaped them. The Jamaica negroes suffered less from their effects than any of the other laborers. These fevers were of a malarial nature, and returned at intervals of four to five weeks, according to the individual. They did not assume a malignant nature and no fatalities resulted from them, but they were a source of considerable annoyance and directly or indirectly caused frequent interruptions in the work. Whenever work of this nature is performed in the tropics more or less fever is apt to develop; it cannot be avoided, but with good care and by the enforcement of sanitary regulations, it can be prevented from developing into a dangerous epidemic. This trying period only lasts during construction.

Handling Ore.—The main manganese ore deposit lies in the district enclosed by creeks *A* and *E*, Fig. 1. The former is in what is called the Nispero mine, and the latter in the Soledad. The distance between both creeks is about half a mile. From both the Nispero and Soledad terminals of the railroad the ground rises very rapidly toward the summit marked *S* in the plan. This point is about 2 000 ft. horizontally from the Nispero terminal of the railroad and 500 ft. above it. The flanks of the mountain are cut up by several narrow gulches and ravines. For the transportation of the ore to the railroad cars, iron side-dumping mining cars of about $\frac{1}{2}$ cu. yd. capacity are used, running on light portable track. The first track laid started from the top of the ore pocket at the Nispero terminal of the railroad. It was built along the side hill with a light rising grade of from $1\frac{1}{2}$ to 2%, so as to allow the loaded cars to go down almost by themselves and at the same time allow the empty cars to be pushed up without much exertion. Similar lines were graded and laid at vertical intervals of 25, 50 or more feet, as the distribution of the ore required them. Connecting all these lines there is an inclined gravity plane with a grade of 30%, and as the loaded car goes down, it pulls up the empty one. The mining cars are loaded at each different level and pushed to the inclined plane, where they are hooked to the end of the rope and let down to the lower level, when they are unhooked and pushed to the ore pocket and their contents dumped.

In several cases where bodies of ore prevented direct communication for some time between the side lines and the inclined plane, the

FIG. 1.

FIG. 2.

cars, instead of going down the incline, dumped their contents into a chute with an inclination of 45° to allow the ore to roll down to the bottom, where by lowering the gate its contents dropped into the car standing at that lower level or into empty cars standing on the incline. This system has not been extended to more than 150 ft. above the Nispero railroad terminal, as the mining operations are confined to that belt, but the same general system could be extended to cover the whole deposit and by close attention to details the number of handlings of the ore could be reduced to a minimum. After the work becomes higher more economy in operation would probably result from using two self-dumping cars on the gravity incline and confining each car to its own level. The author believes that the use of a wire cable tramway in this case, beside involving a larger expenditure in first cost, would not offer any economy in operation, considering the wide belt over which the ore is spread.

The ore pockets at the Nispero terminal of the railroad hold about 75 tons of ore, and those at the Soledad terminal about 200 tons. The inclination given to the bottom of the ore pockets, floored with 3-in. planks, was 45°, as this was found to allow the ore to slide down without sticking to the plank. Both ore pockets are provided with enough chutes to allow four or five railroad cars to be loaded at once. Plate III, Fig, 2, shows a portion of a train carrying 50 tons of manganese ore, coming down the 5% grade.

The natural conditions of Nombre de Dios Harbor were very favorable for building a wharf at a small expenditure, as the deep water coming very close to the shore, which is of coral formation, allows the construction of a wharf with its length parallel to the shore and from only 30 to 50 ft. wide. Its length is about 200 ft. The steamers can load at the wharf as much as they can carry on a 17-ft. draft, which generally varies from 1 300 to 1 800 tons. To send a larger cargo the remaining portion is lightered to the steamer, which must anchor about 1 500 ft. from the wharf. At the port terminal of the railroad the ore is dumped off the cars from a trestle 10 ft. high running nearly parallel with the wharf and about 100 ft. from it. The manganese is loaded in ore buckets carried on small car trucks which are pushed on rails to the side of the steamer, where she lifts them with her own winches. In this manner by using sixteen buckets, it was possible to handle 400 tons per day of 10 hours, by loading through

two hatches at the same time. By a few contemplated improvements the rate of loading per day could be increased.

The first locomotive in use weighed 25 000 lbs., distributed over two pairs of driving wheels measuring 30 ins. in diameter. The cylinders were 10 ins. in diameter by 14-in. stroke. The wheel base was 5 ft. 3 ins. No difficulty was encountered in running around the sharp curves with this locomotive, and after a year of constant use it did not show any effects of hard usage. Many, but not all, the 40° curves are provided with inner guard rails.

Water is pumped to a water tank in the lower portion of the line by means of a Rider hot-air engine, which proved very serviceable, as there is no boiler to look after and it needs very little care and skill to run it. Both of these considerations are very important factors in those countries where skilled labor is difficult to find and comes very high. The pump in question has a capacity of 400 galls. an hour and has been in use for over a year and a half without giving any trouble.

Cost.—In giving the cost of the various items of the work already mentioned, no portion of the engineering or other general expenses were charged to them.

The average cost of the railroad constructed from Viento Frio to Nispero was $12 000 per mile, the average for the Nombre de Dios branch was $6 800 per mile, including the cost of the wharf, of buildings and dwellings erected at Nombre de Dios, and the improvements at the port terminal. The cost of the 10½ miles of railroad built and equipped averaged $13 400 per mile. This included, beside the equipment of the railroad proper, thirty mining cars and ¼ mile of portable track for the mines, as well as some harbor equipment, such as four 30-ton coppered wooden lighters, two iron buoys, two hoisting engines and derricks for the wharf. The cost of the wharf, buildings, etc., is also included, as well as that of the ore bins, and in fact all expenses incurred, whether in South America or Baltimore, in placing the entire property in working order from the time the author was authorized to begin construction in January, 1894, to December, 1895.

The heaviest work, as well as the most expensive portion of the railroad, was the last half mile, which cost $9 000. The amount of material handled in the grading of this section was 22 000 cu. yds.

The actual cost of the railroad from Viento Frio to Nispero, including equipment for railroad, mines and harbor, turned out to be only

1¼% greater than the estimates made by Mr. E. G. Williams and the author in the spring of 1893, to which reference has already been made. It is fair to state, however, that the unit prices did not agree. Some of the items, like grading, ties and bridge buildings, came out lower than had been estimated; but on the other hand, the general expenses and contingency accounts were higher. The excesses and deficiencies, however, more or less compensated each other, with the final result stated. Changes were also made in the work and equipment, but they compensated each other and had no effect on the final result.

In making estimates for work to be performed in the tropics it must be borne in mind that in starting enterprises in these countries many expenses have to be incurred that would be foreign to a similar enterprise in the United States. It is true that labor is generally cheaper per day, but not so in view of the amount of work it accomplishes, with few exceptions in some particular lines which do not count for much in the long run. A doctor must be kept on the ground. The hospital account must be considered as well as its indirect effect in contributing to lengthen out the work and decreasing the value of physical exertion. Due allowances must be made for the transportation of the material to the nearest port and also for local transportation, which is generally very poor. There are also many other minor considerations inherent to all new enterprises in a new country, which, if not fully provided for, will overrun the estimated contingency account.

The author is pleased to acknowledge the valuable co-operation of the engineers associated with him in this work. He has already mentioned the connection of Mr. E. G. Williams with the early stages of the work, with whose able co-operation the first location of the railroad from Viento Frio was made. For all the work performed and described in this paper from the time construction was inaugurated, the writer is indebted to Messrs. R. M. Arango and C. C. Arosemena. Both were connected with the company from January, 1894, the former having been Principal Assistant Engineer to January, 1895, and the latter from that date to July of the same year.

CORRESPONDENCE.

Mr. Cummings ROBERT A. CUMMINGS, Assoc. M. Am. Soc. C. E.—In recent work with unskilled labor in a semi-tropical region, under similar conditions to those described in the paper, the method of paying the men bi-weekly at a fixed rate per day was too much of an innovation to satisfy the natives. Daily and monthly payments were tried with equal inconvenience to employer and employee. Finally task work was adopted and considered satisfactory by the men, although not entirely so by their employer, as little economy resulted. Then a system of rewards for rapid and efficient task work was introduced, the rewards being inexpensive things regarded as luxuries by the men, and in this way a saving of 10% to 50% was effected, the gain depending in part on the individual and in part on the nature of the award.

In making preliminary surveys through such heavily timbered regions as described by the author, the writer has recently obtained very satisfactory results by using a surveyor's compass and a 100-ft. chain for running angle and grade lines, and by using a clinometer for cross-section work. On these surveys, which extended several miles through dense woods and swamps, the writer acted as his own instrumentman, with natives as chainmen. The work checked up quite accurately for the purposes of the survey.

With regard to the slides that are stated in the paper to have occurred in the cuts after construction was completed, the writer has found that the heavy clays from which a seepage of water took place were invariably troublesome, and required a slope in some cases of four to one, depending on the degree of saturation. When the clay was stiff and contained a normal amount of moisture, a nearly vertical cut was preferable, being less exposed to the elements. The dry cuts usually left by steam shovels maintain themselves and are frequently found unchanged after the lapse of a considerable period, which is thought to be due largely to the verticality of the slopes.

As supplementary to the author's notes concerning timber, it may be stated that the *torregia taxifolia*, or stinking cedar, found along the Appalachicola River in Florida, has a wood remarkably durable when exposed to the warm, humid climate of the district. The life of fat yellow pine is but six or seven years, whereas this cedar is unappreciably affected in the same length of time. A bottom rail in a worm fence dividing a swamp from hummock land, which was removed after being in place 38 years, was still in good condition.

Mr. Gould. E. SHERMAN GOULD, M. Am. Soc. C. E.—As the author truly remarks, the aim in the construction of such roads as he describes is to have the line established, and trains running over it, as quickly and cheaply as possible, consistently with reasonably permanent installa-

tions. In the case of the road described in the paper, the amount of traffic could be estimated in advance more easily and accurately than in the general case of a road built to develop a business not already existing. With the latter class of lines, cheap and rapid construction is highly desirable in order that the paying possibilities of the roads may be demonstrated. It is generally difficult to raise the money for a projected road the profits of which exist only in the prospectus of the promoters. If even a temporary line can be laid and operated with large earnings, there will be far less difficulty in placing bonds for improvements and extensions than in attempting to bond a mere concession for a road not yet built. Mr. Gould.

It is to be regretted that sufficient time has not elapsed to determine the relative durability of the native timber and Georgia pine. One serious difficulty in making preliminary estimates on such work as that described in the paper is due to the meager information concerning the cost of timber, particularly ties. It is hard to arrive at a reasonably accurate estimate of the cost of the native timber, even from information obtained on the ground, because when the time comes for making contracts prices may be expected to vary considerably from those given first. The author states that ties of native timber averaged 25 cents apiece, which is remarkably low, but it appears many decayed very rapidly, so it is fair to conclude they were of inferior wood. On the other hand he says lignum vitæ ties on the Panama Railroad cost as high as $1 80 per tie, which price, in connection with their great weight and the cost of boring holes in them for spikes, makes their use very expensive. If it is found that ties of Southern pine, either in an untreated state or creosoted, will resist the attack of tropical ants for even two or three years, this knowledge will greatly facilitate the making of correct estimates for such roads.

The author indicates correctly that estimating on work to be done in the tropics is quite different from figuring the cost of similar work in the United States. It requires considerable experience, the introduction of a liberal estimate for contingencies, or both, to provide for the unforeseen conditions sure to be found, and it is best to make allowances for these from the outset.

José R. Villalon, Assoc. M. Am. Soc. C. E.—It is generally considered by people living in temperate climates that the moon does not exert any influence on timber, and that the belief in this influence, so common in tropical countries, is only a superstition held by uneducated classes. The following remarks show that the belief is not a superstition, but knowledge gained from actual observation: Mr. Villalon.

A few years ago while the writer was engaged on the Antioquia Railroad, in the United States of Colombia, it was necessary to pass through country where water was scarce and unfit for drinking. Under these circumstances it was customary to search for a large

Mr. Villalon. species of bamboo about 8 to 10 ins. in diameter and 2 ft. from joint to joint. If the moon was in the first half, plenty of water was always to be had by making a hole just above a joint, so as to empty the space within the cane between that joint and the next above. When no water was to be had from the bamboo in this locality, the moon was invariably in its last quarter. To secure drinking water in other localities along the same railroad, a species of vine about 3 or 4 ins. in diameter was cut into pieces about 3 ft. long; if this was done during the first half of the moon one or two glasses of sweet pinkish sap was obtained, although the yield was very slight during the last quarter of the moon. The writer had a similar experience with another vine in Cuba.

It is a well-known fact in Cuba and Colombia that bamboo, vines and various relatively soft woods, when cut during the first half of the moon do not last over six months on account of the rapid fermentation of the sap, while if cut during the last quarter they remain for years in very good condition. The durability of timber cut during the waning moon depends greatly on its age; it lasts longest when neither too young nor too old. The same effect is clearly seen in the case of structural timbers; the soft part containing the most sap is the first to decay, if cut during the first half of the moon, while the heart is attacked more slowly. Timber felled during the last quarter lasts a very long time. Not only is the wood subject to this influence of the moon, but leaves, stems and other parts of the tree.

The palm is one of the most useful trees in the tropics; many portions are employed in the construction of country houses, the outer part is used for boards, its leaves serve for thatch, and the leaf stalks are used to cover the outside of houses, for packing tobacco in bales, and for many domestic purposes. It is always the case that if the tree is felled or the leaves cut during the first half of the moon, only a few months of serviceability are to be had, while if cut during the last quarter a service of ten or twelve years may be expected. The writer is reliably informed that in one instance a thatch made of palm leaves cut during the last quarter of the moon was in good condition 32 years after it was placed.

This practice of timber felling is so general in the tropics, and is so decidedly approved by all classes, that in all contracts and specifications a clause is generally inserted requiring the timber to be felled during the waning of the moon; when not so stated, it is always understood. In some cases the timber is felled one or two years in advance, not only to have it well seasoned before use, but also to detect, by its decay, if it has been felled during the first half of the moon. Mr. J. M. Fernandez, in his book on Cuban agriculture, states that the felling of trees during the last half of the moon is clearly required by experience in such matters on the island, and

recommends doing this work during the last quarter. It should also be remarked that in an order to the French Forestry Commissioners, Napoleon I directed the felling of trees for naval timber to be done only between November 1st and March 15th, and during the waning moon. Mr. Villalon.

These facts warrant the following conclusions:

First.—In the tropics the moon exerts an influence on the circulation of the sap in trees, there being the least circulation while the moon is waning.

Second.—In the tropics, where the difference between the seasons is hardly noticeable, the circulation of the sap is continuous, the rate varying with the quarter of the moon.

Third.—It being the universal practice to fell trees for timber when the wood contains the least sap, it follows that the tropical practice of doing this work during the waning moon is fully justified, and agrees with the practice in more temperate climates of doing the same work during the winter.

E. J. Chibas, Assoc. M. Am. Soc. C. E.—The remarks made by Mr. Cummings concerning slides and the stability of slopes in clay cuts agree with the observations of the author. Two of the slides on the road described in the paper were not due to the character of the clay itself, however, but to the presence of a thin, inclined layer of permeable material embedded in it. After heavy rains, water passed through this layer and seemed to give it somewhat the character of a lubricating material, causing the upper bed of clay to slide over the lower practically motionless mass. The layer of permeable material was only a few inches thick, and could be traced easily along the sides of the cut. Mr. Chibas.

Mr. Villalon's observations concerning the influence of the different phases of the moon on the circulation of sap in tropical plants substantiates the author's statement in the footnote on page 77. It might be added that persons engaged in the rubber industry in Colombia always tap the rubber trees during the period preceding the full moon. They claim repeated experience has taught them that the sap is then more abundant, and that they obtain more than if the operations were carried on during the waning moon. All agree that to obtain the best timber trees should be felled when the vegetation is at rest. In temperate countries this happens during midsummer and midwinter, and, therefore, these two periods are selected for such work. In the tropics, where there is no appreciable difference in temperature throughout the year, the seasons seem to have little influence on the circulation of the sap, the minimum quantity being found about once a month. This condition of minimum circulation appears to coincide always with the waning moon, so it is fair to conclude that the moon exerts a certain influence on the circulation of the

Mr. Chibas.

sap. Since the paper was written the author has been informed that the practice of felling trees for timber during the waning moon is not confined to the tropics, but is also followed to some extent in parts of Southern Europe, particularly in Italy.

With reference to Mr. Gould's remarks, the author would state that ties of Southern pine will last for two or three years in the Republic of Colombia, and at least double that time if they are creosoted. As none of the available timber around Nombre de Dios had been employed for ties, it was necessary to experiment with several kinds. Some proved to be of a poor quality and decayed within a year, but from all appearances a large majority will probably outlast the more costly Southern pine.